production of stains is through the cooperation of scientists. After determining some one reliable line of stains we should make this line standard as the Grübler stains were once, and discourage the entrance of new manufacturers into this rather limited field. The line selected as standard need not be all the output of any one laboratory; but the production of *any one stain* in several different laboratories is an unnecessary waste of effort. All the distributors of stains are anxious to avoid this sort of duplication, and whenever one has been approached in the matter, most hearty cooperation has been assured us.

To carry out this program means considerable preliminary work to determine which of the domestic sources of each stain is the most reliable. Although we have considerable light on this subject already, and can in many cases make private suggestions of possible value to purchasers, we have not as yet the data necessary for making any official statement. We are now planning a series of tests of the most important bacteriological dyes in a considerable number of different laboratories, the outcome of which may determine our future action in the matter. As a society of bacteriologists we are of course primarily interested in the most commonly used bacterial stains, such as fuchsin, methylen blue, the gentian violet group, and the prepared blood stains. Secondarily, however, we are interested in securing the cooperation of other biologists in an attempt to standardize eventually the whole field.

This article is being written in the hopes of securing this cooperation. We wish to invite other biologists as individuals and through their organizations to work with us in the matter. Any one interested in our purpose is urged to communicate with the committee.

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GENEVA, N. Y.,
March 1, 1921

SPECIAL ARTICLES

THE STRUCTURE OF THE STATIC ATOM

IN attempting recently to derive the conditions which determine the stability of chemical molecules I was impressed by the importance of the part played by Coulomb's law of inverse square forces between charged particles. In fact, by considering a static arrangement of electrons according to the models which I proposed two years ago, and calculating the total potential energy by Coulomb's law, I have found it possible not only to determine the relative stability of various substances but to calculate with reasonable accuracy the heats of formation of compounds even of widely varying types.

In all such calculations, however, it is necessary to assume that the electrons are kept from falling into the nucleus by some undetermined force, for Coulomb's law alone can not account for this. According to Bohr's theory of atomic structure, the requisite repulsive force is nothing more than centrifugal force due to rotation of the electrons about the nucleus. This theory has been so remarkably successful in accounting for the spectra of hydrogen and helium that the fundamental assumption of movement about the nucleus has seemed justified, notwithstanding the fact that this violates all our classical laws regarding the radiation of energy from accelerated electrons.

From the chemical point of view it is a matter of comparative indifference what the cause of the repulsive force is, so long as it exists. I therefore endeavored to find what law of repulsive force between electrons and positive nuclei would produce an effect equivalent to the centrifugal force of Bohr's theory.

According to Bohr the average kinetic energy in any atom or molecule is half as great as the average potential energy, but opposite in sign. I therefore now assume that this energy, which Bohr called kinetic, is another form of potential energy dependent upon certain quantum changes in the electron.

From this potential energy it is then easy to determine the law of repulsive force.

The result of this analysis is that we may regard the force between any nucleus of charge Ze and an electron of charge e as consisting of two parts which act independently. The first is the Coulomb attractive force F_c given by

$$F_c = \frac{Ze^2}{r}. \tag{1}$$

The second force, which we may call the *quantum force* is a repulsive force F_q given by

$$F_q = \frac{1}{mr^3}\left(\frac{nh}{2\pi}\right)^2. \tag{2}$$

In these equations r is the distance between the electron and the nucleus, m is the mass of the electron, h is Planck's quantum, and n is an integer denoting the quantum state of the electron. This repulsive force, varying inversely as the cube of the distance, is remarkable in that it is independent of the charge on the nucleus. It is to be noted especially that an electron which has not undergone any quantum change and for which therefore $n = 0$, follows Coulomb's law accurately. Thus presumably β-rays in passing through an atom will be acted on only by the usual law.

It can be readily shown that under the influence of these two forces an electron will be in stable equilibrium when it is at a distance from the nucleus equal to

$$a = \frac{n^2 a_0}{Z}, \tag{3}$$

where a_0 is given by

$$a_0 = \frac{h^2}{4\pi^2 me^2}. \tag{4}$$

This result is identical with that for the radius of the orbit in Bohr's theory, but of course the law of force was chosen to give just this result.

If W is the total energy of the system with its sign reversed we obtain

$$\frac{W}{W_0} = \frac{2Za_0}{r} - \frac{n^2 a_0^2}{r^2}, \tag{5}$$

where

$$W_0 = \frac{2\pi^2 me^4}{h^2}. \tag{6}$$

Equation (5) has no equivalent in Bohr's theory for it applies to the transitions between stationary states. The first term in the second member represents the Coulomb potential while the second corresponds to the quantum potential.

When an electron has settled down into its position of equilibrium, the value of W becomes

$$W = \frac{Z^2 W_0}{n^2}. \tag{7}$$

This also is identical with the result obtained by Bohr for the total energy in any stationary state. It follows from this that the Rydberg constant, the Balmer series and all other series calculated by Bohr can be obtained by this method without assuming electrons moving about the nucleus.

If the electron is disturbed from its position of equilibrium it oscillates about this position. From equation 5 the frequency of this oscillation is found to be

$$\nu = \frac{4\pi^2 Z^2 me^4}{n^3 h^3}. \tag{8}$$

This is identical with the frequency of revolution of the electron in Bohr atom. From this we may draw a definite physical picture of the mechanism of the transition between two states, at least when Z is large. Bohr has shown that under these conditions the frequency radiated when an electron passes from one circular orbit to the next inner one is the same as the frequency of revolution. According to the present theory, if the quantum number of an electron in a stable position decreases by one unit, the electron is no longer stable but falls towards its new position of equilibrium, and oscillates about this position. It then radiates its energy of oscillation according to the usual laws of electro-dynamics.

One of the greatest successes of the Bohr theory is that it accounts for certain slight differences between hydrogen and helium lines

by the nuclear mass correction. This correction is taken care of in the present theory with the same accuracy if we assume a slight modification to our law of quantum repulsion, viz. replace equation (2) by

$$F_q = \left(\frac{nh}{2\pi}\right)^2 \frac{\frac{1}{m} + \frac{1}{M}}{r^3}, \qquad (9)$$

where M is the mass of the nucleus. This seems to indicate that the quantum force is due to an interaction between the electron and the nucleus in which both masses play a similar rôle. For example, it may be imagined that both are set into rotation in opposite directions about the axis connecting them.

Sommerfield has accounted for the fine-line structure of spectral lines by considering a relativity correction due to the rapid motion of the electron. This would seem to be excellent proof that the electrons do move. However, it is possible that the motion resides within the electron and nucleus. It is probably significant that the relativity correction can be taken into account in the present theory if we substitute in equation 2 in place of n^2 the expression

$$(n_a + n_r)^2 - \alpha^2 Z^2 \left(\frac{n_r}{n_a} + \frac{1}{4}\right), \qquad (10)$$

where α is a constant calculated by Sommerfeld. A consideration of this equation may lead to more definite conceptions of the structure of the electron and nucleus. The quantities n_a and n_r refer to what Sommerfeld calls angular and radial quanta. It is not yet clear just what interpretation is to be placed upon these in the present theory but they are evidently only of secondary importance in determining the forces between the electrons and the nucleus.

When we consider other atoms such as helium it seems as if the new theory may lead us much further than the usual theory, for the determination of equilibrium positions under static forces is extremely simple compared to the corresponding dynamical problem. Furthermore we are not troubled by mysterious quantum conditions which are theoretically applicable only to periodic orbits while the calculated orbits in atoms are not periodic.

At present I am studying the spectra of helium and lithium from this viewpoint. The following tentative conclusions may be stated.

The quantum force between quantized electrons is not as simple as between electrons and nuclei. The quantum force between electrons on opposite sides of a nucleus is one of repulsion whose magnitude is approximately given by equation (2) if the quanta are all of the "angular" type, but is considerably less when the quanta are of the "radial" type. But if the electrons are on the same side of the nucleus, the quantum force between electrons is one of attraction, also given approximately by equation (2). Thus if one of the electrons in the helium is uniquantic, and the other one is diquantic, the latter can take equilibrium positions either on the opposite side of the nucleus from the uniquantic electron or on the same side. This perhaps explains the fact that helium (as well as other elements with two outer electrons such as calcium, etc.) has two separate complete sets of spectra (helium and parhelium). It is also in accord with the remarkable facts in regard to the helium spectrum which were recently pointed out by Franck and Reiche.

These properties of the electron are in full accord with those which are needed to account for chemical relationships. The new theory fulfills the predictions of G. N. Lewis who in 1916 wrote[1] in reference to Bohr's theory:

> Now this is not only inconsistent with the accepted laws of electromagnetics but, I may add, is logically objectionable, for that state of motion which produces no physical effect whatsoever may better be called a state of rest.

It is also in accord with the conclusion which I gave in a paper entitled "The properties of the electron as derived from the chemical properties of the elements,"[2] viz.:

[1] *Jour. Amer. Chem. Soc.*, 38, 773 (1916).
[2] *Phys. Rev.*, 8, 300 (1919).

How can these results be reconciled with Bohr's theory and with our usual conception of the electron? It is too early to answer. Bohr's stationary states and the cellular structure postulated above have many points of similarity. It seems that the electron must be regarded as a complex structure which undergoes a series of discontinuous changes while it is being bound by the nucleus or kernel of an atom. There seems to be strong evidence that an electron can exert magnetic attractions on other electrons in the atom even when not revolving about the nucleus of the atom.

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March 8, 1921

THE OKLAHOMA ACADEMY OF SCIENCE

THE ninth annual meeting was held in Oklahoma City on February 11, at the State University, Norman, on February 12. The following papers were read:

Presidential Address: *Research in secondary schools:* A. F. REITER.

The organization of a research council in Oklahoma: GUY Y. WILLIAMS.

On the affiliation of the Oklahoma Academy of Science with the American Association for the Advancement of Science: L. B. NICE.

The ceremonies and rites incident to eating peyote among the Cheyenne Indians: J. B. THOBURN.

The intrinsic-extrinsic mechanism of heredity and variation: H. H. LANE.

An eccentric hen—anatomically excused: A. F. REITER.

On the non-singular cubic: NATHAN ALTSCHILLER-COURT.

A survey of the taxation system of Oklahoma: F. F. BLACHLY.

The teaching efficiency of motion pictures measured in terms of results secured under schoolroom conditions: J. W. SHEPPARD.

Where did the Indians of the Great Plains get their flint? CHAS. N. GOULD.

An objective view of education in Oklahoma: MIRIAM E. OATMAN-BLACHLY.

The most important scientific spot on earth: WALT B. SAYLER.

An observation on the male Dickcissel during the nesting period: ED. CRABB.

The genetic evidence of a multiple (triple) allelomorph system in bruchus and its relation to sex-limited inheritance: J. K. BREITENBRECHER.

Some studies with complement deficient guinea pigs: H. S. MOORE.

The migration path of the germ cells in fundulus: A. RICHARDS and J. T. THOMPSON.

Nesting of mourning doves at Norman in 1920: MARGARET M. NICE.

Some notes on winter birds around Norman in 1920–21: MARGARET M. NICE.

A comparison of the rate of diffusion of certain substances, particularly the food materials, enzymes and pro-enzymes: ALMA J. NEILL.

Further observations on tonus rhythms in diaphragm muscle: L. B. NICE and A. J. NEILL.

A child's deviations from truth: SOPHIA R. ALTSCHILLER-COURT.

The range of vocabulary at eighteen months of age: MIRIAM E. OATMAN-BLACHLY.

Relation of science to art: LUCILLE CARSON.

The bank of Missouri: J. RAY CABLE.

A plan to reach the Orinoco sources: T. A. BENDRAT.

The cliff-dwellers in Mesa Verde Park, Colorado: C. W. SHANNON.

A trip across the Navajo desert: JUANITA RAMSEY.

Evidence on the Pennsylvania glaciation in the Arbuckle Mountains: S. WEIDMAN.

Toyah, Texas, oil pool: BESS MILLS.

The Marietta syncline and its effect upon the physiography of Love County: FRED BULLARD.

Deep tests in southwestern Oklahoma: WALDO PORTS.

Protozoa of Colorado: T. C. CARTER. (Read by title.)

The grand period of growth of root-hairs: R. E. JEFFS. (Read by title.)

During the session it was voted to affiliate the Oklahoma Academy of Science with the American Association for the Advancement of Science forming two classes of members, local and national.

It was also voted to establish a State Research Council in the Oklahoma Academy of Science along the same plan as the National Research Council.

It was further voted to establish a Natural History Exchange for the purpose of assistance in building museums in the colleges and high schools of the state.